# 8.0 BACT "TOP DOWN" ANALYSES

## 8.1 Project Description

**A BACT analysis was performed for a gas-fired calciner (Source ID AQD #48). The pollutant of concern is VOC's and, therefore, this BACT analysis only addresses control technology for VOCs.**

Calciner process information was obtained from Solvay Soda Ash Joint Venture. The process parameters used in determining the cost estimates are:

| | |
|---|---|
| ■ Flue Gas Flow Rate (actual conditions): | 160,000 acfm |
| ■ Flue Gas Flow Rate (standard conditions): | 54,507 dscfm |
| ■ Flue Gas Temperature: | 315°F |
| ■ Flue Gas Moisture Content: | 36% water (by volume) |
| ■ Flue Gas $CO_2$ Content: | 10% $CO_2$ (by volume) |
| ■ VOC Emission Rate: | 151 lb/hr |
| ■ VOC Concentration: | 400 ppm |

## 8.2 Best Available Control Technology (BACT) Review

BACT is selected using a top-down analysis as described in the "*New Source Review Workshop Manual*, Draft, October, 1990," OAQPS, EPA. The analysis consists of five steps, summarized below:

1) Identify control technologies.
2) Eliminate technically infeasible options.
3) Rank remaining control technologies by control effectiveness.
4) Evaluate most effective controls and document results.
5) Select BACT.

The *New Source Review Workshop Manual* offers a number of sources of information to identify alternate control technologies such as the *RACT/BACT/LAER Clearinghouse*, Federal/State/local new source permits, control technology vendors, etc. Each of these sources were used to identify candidate control technologies for the subject calciners.

## 8.3 Volatile Organic Compound (VOC) BACT Analysis

Hydrocarbon emissions are generated from the calciner operations during which crushed trona ore is heated (calcined). These emissions may be either from noncombusted fuel (natural gas) or from the organics inherent in the trona ore. The majority of the hydrocarbons from the noncombusted fuel would be methane and ethane, which are not VOCs. Therefore, the majority of the VOC emissions from the calciner stack are assumed to be from the trona ore.

### 8.3.1 Calciners

A search was conducted from the *RACT/BACT/LAER Clearinghouse* for determinations on *calciners and dryers and minerals processing facilities*. Control technology vendors were also contacted to determine the technical and/or economical feasibility of controlling VOC emissions in calciner flue gases.

Five (5) control technologies for VOC emissions were identified:

- catalytic oxidation,
- carbon adsorption,
- condensation,
- thermal decomposition, and
- good combustion practices.

Calculations for the BACT "Top Down" Analysis are included in Appendix D.

### 8.3.2. Catalytic Oxidation

Remedial Systems, Inc. provided information for catalytic oxidation whereby the VOCs can be oxidized by combusting the stream over a catalyst.

The largest unit manufactured by Remedial Systems is a 5,000 acfm unit at a cost of $80,000.

To accommodate the calciner flow of 160,000 acfm would require thirty-two units. Along with other direct costs, there is a total capital cost of approximately $5.1 million. Amortizing this cost (15 years @ 10%) and using reasonable annual operating costs, the total annual cost would be $3.0 million. Based on 95% effectiveness in removing the 661 TPY of VOCs, the cost effectiveness of this control technology is $4,709/ton (Refer to Table 8-1).

These cost estimates do not include the disposal/recycle cost for the spent catalyst (requires replacement every five years), which would increase the annual cost and decrease cost effectiveness. (This cost was not factored in because it is highly variable depending on the catalyst selected.) In addition, the burning of natural gas due to the supplemental fuel requirement would create additional quantities of $NO_x$ and CO emissions.

### 8.3.3 Carbon Adsorption

Westport Environmental Systems provided information on a carbon adsorption/regeneration system.

In this process, the VOCs are adsorbed onto a carbon bed. The carbon must be regenerated and this process creates a wastewater stream.

The total capital cost of a carbon regeneration system would be approximately $7.9 million.

Amortizing this cost (15 years @ 10%) and using reasonable annual operating costs, the total annual cost would be $2.7 million. The cost effectiveness of this system, based on 95% removal of 661 TPY VOC, is $4,346/ton (Refer to Table 8-1).

The wastewater disposal and carbon disposal (once the active life is used up) are impacts which have not been quantified and would increase the annual cost and decrease cost effectiveness. Carbon life and thus disposal cost is highly variable and therefore is not quantified. Wastewater disposal costs are highly variable depending on the disposal option chosen, therefore it is not quantified.

### 8.3.4 Condensation

Edwards Engineering has provided information for vapor condensation of the VOCs from the waste stream.

Their system will use rotor concentrators to concentrate the vapor stream prior to entering the vapor recovery system, consisting of a mechanical refrigeration system. The recovered waste stream would likely require incineration at a hazardous waste facility. A very large quantity of water (approximately 0.25 billion tons) would be generated annually and require disposal. This water is driven off the trona during the calcination process, converting trona to soda ash with the liberation of water and carbon dioxide. ($Na_2CO_3$-$NaHCO_3$-$2H_2O$ to $Na_2CO_3$ + $H_2O$ + $CO_2$.) Wastewater disposal cost is highly variable depending on the disposal option chosen, therefore it is not quantified.

Amortizing the total capital costs of $9 million (15 years @ 10%) and using reasonable annual operating costs, the total annual cost would be $3.1 million. The cost effectiveness of the condensation/incineration system, based on 99% removal of the VOCs, is $4,734/ton (refer to Table 8-1).

### 8.3.5 Thermal Decomposition

Information on flares was provided by John Zink.

The waste stream can be combusted in a flare, but because the heat value of the stream is low, natural gas would have to be added to bring the heat value of the stream up to the required 200 Btu/ft$^3$.

Due to the large flow rate (160,000 acfm), 2.7 MMscf/hr of natural gas would be required. This large amount of natural gas causes two significant challenges.

The fuel cost alone would be more than $47 million/year, making the use of a flare highly cost prohibitive. Additionally, the VOC emissions from the flare (natural gas necessary to support combustion) would be more than the existing emissions (759 TPY VOC vs. 661 TPY VOC). There would also be significant amounts of CO and $NO_x$ emission generated by the fuel combustion.

[redacted]



Because there would actually be an increase in VOC emissions from the flare, it is considered not applicable as a control device.

Other methods of thermal decomposition include incineration (with cost concerns similar to the flare), regenerative thermal oxidation (in the $6,000-10,000/ton range) and recuperative incinerators (in the $15,000-20,000/ton range).

### 8.3.6 Good Combustion Practices

The current operation of the calciner provides "good combustion practices" and the firing of a "clean fuel" (natural gas). However, this does not reduce the VOC emissions resulting from calcining the trona ore, which inherently contains volatile organics.

## 8.4 BACT Summary

Considering energy, environmental, and economic impacts, it has been determined that the VOC controls (described in 8.3.2 through 8.3.5) proposed for BACT are neither technically feasible nor economically reasonable. Solvay Soda Ash Joint Venture proposes "Good Combustion Practices" (firing of natural gas) as BACT for the Calciner, AQD #48.

The BACT summary for the control technologies is provided in Table 8-1.

[redacted]



**TABLE 8-1**
**Summary of Top-Down BACT Analysis Results**

| Pollutant | Emission Unit | Control Alternatives | Emissions | | Emissions Reduction TPY | Economic Impacts | | Environmental Impacts | | Energy Impacts Incremental Increase over Baseline yes/no |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | lb/hr | TPY | | Total Annualized Costs $/yr | Average Cost Effectiveness $/ton | Toxics Impacts yes/no | Adverse Env Impacts yes/no | |
| VOC | Gas Fired Calciner AQD #48 | Catalytic Oxidation - 95% | 7.6 | 33 | 628 | 2.958.517 | 4.709 | No | Yes (1) | Yes |
| | | Carbon Adsorption - 95% | 7.6 | 33 | 628 | 2.730.494 | 4.346 | No | Yes (2) | Yes |
| | | Flare - 98% | 173 | 759 | (98) | 47.469.306 | N/A (5) | No | Yes (3) | Yes |
| | | Condensation - 99% | 1.5 | 6.6 | 655 | 3.099.496 | 4.734 | No | Yes (4) | Yes |
| | | High Temp. / High Residence Time Combustion | 151 | 661 | 0 | 0 | - | N/A | N/A | N/A |

NOTE. Parentheses denote negative values.

(1) The spent catalyst may be a hazardous waste and will require disposal.
(2) The carbon regeneration process will create a hazardous waste stream to be disposed.
(3) The flare emissions from the firing of supplemental fuel will be greater than the emissions from the existing process.
(4) The condensate from this process will require incineration.
(5) Cost effectiveness is not applicable because the proposed added control will increase VOC emissions.

[redacted]



## Control Technology Cost Analysis

| | | | | | Control Technology | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Catalytic Oxidation | Carbon Adsorption | Flare | Vapor Condensation |
| **Capital Costs** | | | | | | | | |
| Direct Costs: | Purchased Equipment | | | | | | | |
| | Basic Equipment | | | $ | 2,560,000 | 3,942,016 | 225,258 | 4,505,161 |
| | Auxiliaries (35% Basic Equipment) | | | $ | incl above | incl above | incl above | incl above |
| | Instrumentation (10% Basic Equipment) | | | $ | incl above | incl above | incl above | incl above |
| | Structural Support (10% Basic Equipment) | | | $ | 256,000 | 394,202 | 22,526 | 450,516 |
| | Tax & Freight (8% Sum of above 4 lines) | | | $ | 225,280 | 346,897 | 19,823 | 396,454 |
| | Installation, Direct (30% Sum of above 5 lines) | | | $ | 912,384 | 1,404,935 | 80,282 | 1,605,639 |
| Total Direct Cost (TDC): | | | | $ | 3,953,664 | 6,088,050 | 347,889 | 6,957,771 |
| Indirect Costs: | Installation, Indirect | | | | | | | |
| | Engineering & Supervision (10% TDC) | | | $ | 395,366 | 608,805 | 34,789 | 695,777 |
| | Construction & Field Expenses (10% TDC) | | | $ | 395,366 | 608,805 | 34,789 | 695,777 |
| | Construction Fees (5% TDC) | | | $ | 197,683 | 304,402 | 17,394 | 347,889 |
| | Contingencies (3% TDC) | | | $ | 118,610 | 182,641 | 10,437 | 208,733 |
| | Other Indirect Costs | | | | | | | |
| | Start-up & Performance Tests (1% TDC) | | | $ | 39,537 | 60,880 | 3,479 | 69,578 |
| Total Indirect Costs (TIC): | | | | $ | 1,146,563 | 1,765,534 | 100,888 | 2,017,754 |
| Total Capital Costs (TDC + TIC): | | | | $ | 5,100,227 | 7,853,584 | 448,776 | 8,975,525 |
| Working Capital (1.7% TDC) | | | | $ | 67,212 | 103,497 | 5,914 | 118,282 |
| **Annual Costs** | | | | | | | | |
| Direct Costs | | | | | | | | |
| | Direct labor | 2000 hrs x | 12.02 $/hr = | $ | 24,040 | 24,040 | Neg | 24,040 |
| | Supervision | 0 hrs x | 15.63 $/hr = | $ | 0 | 0 | Neg | 0 |
| | Maintenance | 1000 hrs x | 14.63 $/hr = | $ | 14,630 | 14,630 | Neg | 14,630 |
| | Replacement parts (1.5% of equipment cost) | | | $ | 38,400 | 59,130 | 3,379 | 67,577 |
| | Catalyst (5 yr life) | rec factor: | 0.26 | $ | 150,476 | N/A | N/A | N/A |
| | Fuel Usage | Mscf x | 2.0004 $/Mscf = | $ | 1,822,444 | N/A | 47,387,504 | N/A |
| | Electricity | kW*hr x | 0.06 $/kW*hr = | $ | N/A | 431,134 | N/A | 97,985 |
| | Steam | lb/hr x | 0.002801 $/lb steam = | $ | N/A | 46,613 | N/A | N/A |
| | Water | Mgal x | 1.82 $/Mgal = | $ | N/A | 765,274 | N/A | N/A |
| | Waste disp./Inciner. | Tons x | 2,000 $/Ton = | $ | (3) | N/A | N/A | 1,309,532 |
| Total direct costs | | | | $ | 2,049,990 | 1,340,820 | 47,390,883 | 1,513,765 |
| Indirect costs | | | | | | | | |
| Overhead | | | | | | | | |
| | Payroll (30% of direct labor) | | | $ | 7,212 | 7,212 | Neg | 7,212 |
| | Plant (26% of all labor & replacement parts) | | | $ | 20,038 | 25,428 | 879 | 27,624 |
| Total overhead | | | | $ | 27,250 | 32,640 | 879 | 34,836 |
| Capital charges | | | | | | | | |
| | G&A taxes & insurance (4% of total capital cost) | | | $ | 204,009 | 314,143 | 17,951 | 359,021 |
| | Capital recovery cost (capital cost x recovery factor) | | | $ | 670,546 | 1,032,540 | 59,002 | 1,180,046 |
| | Cap recovery factor (15 yr, 10%) | | 0.13 | | | | | |
| | Interest on working capital (10% of working capital) | | | $ | 6,721 | 10,350 | 591 | 11,828 |
| Total capital charges | | | | $ | 881,276 | 1,357,033 | 77,545 | 1,550,895 |
| **Total Annualized Costs** | | | | $ | 2,958,517 | 2,730,494 | 47,469,306 | 3,099,496 |
| VOC Emissions - Uncontrolled | | | | TPY | 661 | 661 | 661 | 661 |
| Control Efficiency | | | | % | 95% | 95% | 98% | 99% |
| VOC Emissions - After Control Device (2) | | | | TPY | 33 | 33 | 759 | 7 |
| VOC Emission Reduction | | | | TPY | 628 | 628 | -98 | 655 |
| **Cost Effectiveness** | | | | $/ton | 4,709 | 4,346 | N/A (1) | 4,734 |

**Comments:**

Equipment and most costs based on vendor information:

Catalytic Oxidation, Remedial Systems, Inc.
Carbon Adsorption, Westport Env. Sys., Inc.
Flare, John Zink
Condensation, Edwards Engineering Corp.

Additional costs from EPA control cost guidance and industry data.

(1) Cost effectiveness is not applicable because the proposed added control will increase the amount of total VOC emissions.
(2) Emissions for Catalytic Oxidation and Flare have additional VOC emissions due to supplemental fuel firing.
(3) Cost of catalyst disposal/recycle (5 year life) not included.

| Stack Gas Properties | | |
|---|---|---|
| Stack Flow Rate | 160,000 | acfm |
| Stack Flow Rate | 54,507 | dscfm |
| VOC Emission Rate | 151 | lb/hr |
| | 661 | TYP |
| VOC Concentration | 400 | ppm |
| Flue Gas Temp. | 315 | F |
| Flue Gas Moisture Content | 36 | % volume |
| Flue Gas CO2 Content | 10 | % volume |
| Operation | 8,760 | hr/yr |

* per Solvey Minerals (revisions to draft report received 2-9-96).

| Utilities and Disposal Costs | | | | |
|---|---|---|---|---|
| Natural gas cost = | 2.0004 | $/Mscf (Cheyenne Light, Fuel, and Power @ (307)-638-3361). | | |
| | | Note: Cost of natural gas varies considerably. | | |
| | | Cost reported is current and is a conservative estimate. | | |
| Electrical costs = | 0.06 | $/kW hr (Cheyenne Light, Fuel, and Power @ (307)-638-3361). | | |
| Steam costs = | 0.002801 | $/lb steam | | |
| | | Btu to produce steam = | 1,400 | Btu/lb steam (AP-42, Appendix A (4th ed. 9/85)). |
| | | Natural gas heating value = | 1,000 | Btu/scf (AP-42, section 1.4 (4th ed. 9/85)) |
| | | Steam cost = (Btus to produce steam / (gas heat value x 1,000 scf/Mscf)) x natural gas cost. | | |
| Water costs = | 1.82 | $/Mgal (Water Public Utilities (Cheyenne) @ 307-637-6460) | | |
| Incineration costs = | 2,000 | $/ton waste disposal (assumed). | | |

[redacted]



## Catalytic Oxidation

*The following data is per Laura McClellan of Remedial Systems, Inc. (508)-543-1512.*

Largest system commercially available is a 5,000 acfm unit.
APC unit flow rate = 5,000 acfm.
APC equipment unit cost = $80,000 per unit
Calculate number of units and total cost to handle stack flow by scaling.
Number of units = (stack flow rate/APC unit capacity) = 32 units
Total equipment cost = number of units x unit cost = $2,560,000
Total equipment cost includes auxillaries and instrumentation.

Base catalyst cost = $450,000 (based on 43,000 scfm flowrate and 5 year catalyst life).
Catalyst cost = base catalyst cost x (stack flowrate / 43,000 scfm) = $570,422
Catalytic Oxidation Supplemental Fuel Rate = 65,000 Btu/hr per 100 cfm
From vendor supplied supplemental fuel requirement table, based on conservative assumption of 500 ppm VOC in stream.
Supplemental fuel required = waste gas flow rate x supplemental fuel rate
Supplemental fuel = 104 MMBtu/hr
911,040 MMBtu/yr
Natural gas heat value = 1,000 Btu/scf
Natural gas fuel useage = 104 Mscf/hr
911,040 Mscf/yr

| Emissions from supplemental fuel firing | | | |
|---|---|---|---|
| | Emission Factor (1) | Emission (2) | |
| Pollutant | lb/MMscf | lb/hr | TPY |
| PM10 | 5 | 0.5 | 2.28 |
| SO2 | 0.6 | 0.1 | 0.27 |
| NOx | 550 | 57.2 | 251 |
| CO | 40 | 4.2 | 18.22 |
| VOC | 1.4 | 0.1 | 0.64 |

(1) AP-42, section 1.4, tables 1.4-1, 1.4-2, 1.4-3, utility/large industrial boilers (7/93).
(2) Emissions (lb/hr) = fuel (MMscf/hr) x factor (lb/MMscf)
Emission (TPY) = emissions (lb/hr) x 8760/2000

| Carbon Adsorption | | | |
|---|---|---|---|
| *The following data is per Rick Krenmeyer of Environmental Systems, Inc. (800)-343-9411.* | | | |
| Base equipment cost = $3 to $4 million = | $3,500,000 | based on 135,000 acfm flow rate | |
| Scale base equipment cost to handle actual stack flow based on power rule. | | | |
| Equipment cost = base equipment cost x (stack flow rate / base flow rate)^0.7 | | | |
| Equipment cost = | $3,942,016 | for actual stack flow rate | |
| Total equipment cost includes auxillaries and instrumentation. | | | |
| Water useage = | 800 | gpm. | |
| | 420,480 | Mgal/yr | |
| Steam usage = | 1,900 | lb/hr. | |
| | 16,644,000 | lb/yr | |
| Power requirements = | 1100 | hp | |
| Conversion factor | 0.7457 | kw/hp | (CRC, 60th ed.) |
| Power requirements = | 820 | kw | |
| Annual power requirements = | 7,185,565 | kw*hr. | |

## Flare

*The following data is per Kyle Shotz of John Zink, (918)-234-2867.*

Base equipment cost = $200,000 based on 135,000 acfm flare feed.
Scale base equipment cost to handle actual stack flow based on power rule.
Equipment cost = base equipment cost x (stack flow rate / base flow rate)^0.7
Equipment cost = $225,258 for actual stack flow rate

Enrichment gas needed based on vendor supplied empirical equation as follows.
Enrichment gas needed = ( gas stream flow rate x( 200 - waste stream heat value)) / 710.
= 45,070 ft^3/min
= 23,689,014 Mscf/yr
Natural gas heat value 1,000 Btu/scf
= 2,704 MMBtu/hr
Note: waste stream heat value assumed equal to zero (0).

| Emissions from supplemental firing | | | |
|---|---|---|---|
| | Factor | Emissions (1) | |
| Pollutant | lb/MMBtu | lb/hr | TPY |
| Total Hydrocarbons ( | 0.14 | 379 | 1,658 |
| Methane (2) | 0.077 | 208 | 912 |
| VOCs (2) | 0.063 | 170 | 746 |
| Carbon Monoxide | 0.37 | 1,001 | 4,382 |
| NOx | 0.068 | 184 | 805 |

(1) AP-42 Table 11.5-1* Factors (7/93)
(2) Total hydrocarbons = methane + VOC

| Vapor Condensation | | | |
|---|---|---|---|
| *The following data is per Bob Zeiss of Edwards Engineering Co., Prompton Plains, N.J. (201)-835-2800.* | | | |
| Base equipment cost = | $4,000,000 | based on 135,000 acfm waste gas flow rate. | |
| Scale base equipment cost to handle actual stack flow based on power rule. | | | |
| Equipment cost = base equipment cost x (stack flow rate / base flow rate)^0.7 | | | |
| Equipment cost = | $4,505,161 | for actual stack flow rate | |
| Power Requirements = | | 250 | hp |
| Conversion factor | | 0.7457 | kw/hp (CRC, 60th ed.) |
| Power = | | 186 | kw |
| Annual power requirements = | 1,633,083 | | kw*hr. |
| Incineration (waste disposal) = | 655 | TPY | (equal to amount of VOC/organic recovered). |

[redacted]